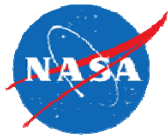




ACAS-Xu Technical Seminar

SSI-East

May 21, 2015



SSI DAA Flight Test Research



December 2014	April – August 2015	Nov 2015	Beyond FY16
GA-FAA-NASA Flight Test	Flight Test 3	Flight Test 4	Flight Tests DAA Phase 2 MOPS
DAIDALUS DAA (SS) guidance tested in flight providing SS maneuver guidance to the pilot-in-command.	DAIDALUS DAA (SS) maneuver guidance algorithm with full sensor suite input, data fusion, and TCAS-equipped intruders in pair-wise encounters	DAIDALUS DAA (CA-SS) maneuver guidance algorithm with integrated TCAS II, with full, sensor suite input, data fusion, and TCAS-equipped intruders in pair-wise encounters	DAIDALUS DAA (CA-SS) tested in Terminal Operations using alternative surveillance sensors for lower altitudes and pattern operations.
Phase 1 MOPS Contribution <ul style="list-style-type: none"> •Initial performance results of SS algorithm testing and operator feedback on “suggestive” SS. 	Phase 1 MOPS Contribution <ul style="list-style-type: none"> •First time “suggestive” SS. •System and Pilot Performance observations 	Phase 1 MOPS Contribution <ul style="list-style-type: none"> •First time “suggestive” SS. •System and Pilot Performance observations 	Phase 2 MOPS Contribution DAA maneuver guidance performance results for terminal operations



Overview



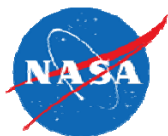
Initial Self Separation Flight Test: SS Algorithm - DAIDALUS (Stratway+)

Goals:

- Verify stability of DAIDALUS with real sensor data
- Receive pilot feedback on DAIDALUS display
- Flight Test 3 Risk Reduction

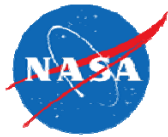
Ikhana UAS – King Air Intruder - 17 Total trials

- Head on, 20, 45, 90, 135 degree
- Sensor varied between Radar only and Radar + ADS-B
- Closest point of approach (CPA) offset between 0 and 1.5nm



DAIDALUS Self-Separation Guidance Display

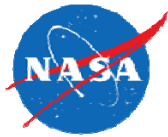




Results



- Sensor Test
 - Self-separation guidance from DAIDALUS was effective
 - DAIDALUS was stable with real sensor data
 - Sensors performed as expected – no outstanding or new issues
- Operator feedback
 - Operator was able to use the DAIDALUS guidance to maneuver
 - Display was usable, understandable
- Risk Reduction
 - Lessons learned have driven decisions for Flight Test 3 and CASSAT
 - Allowed us to mature data collection capability

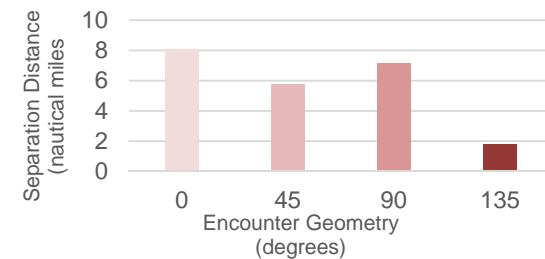


Observations

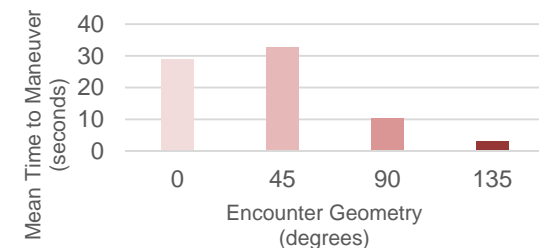


- Alerting time afforded by DAIDALUS reflected in operator behavior
- The operator reacted more quickly in 90 and 135 degree encounters
 - Perceived as more urgent
- DAIDALUS guidance allowed the operator to stay well clear in the challenging 135 degree encounters
- The operator made more dramatic maneuvers than needed
 - Operator “primed” by collision avoidance trials
 - More timely training planned for FT3

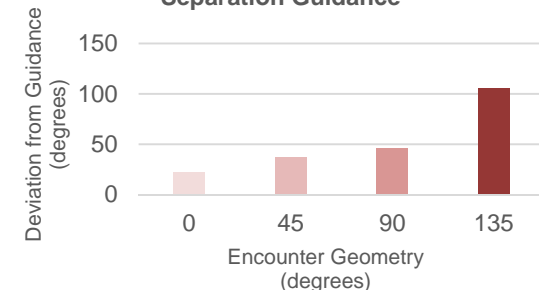
Mean Aircraft Separation Distance at Time of Maneuver

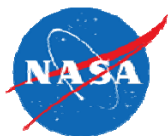


Mean Operator Time to Maneuver from First DAIDALUS Self-Separation Guidance



Pilot Maneuvers Using DAIDALUS Self-Separation Guidance





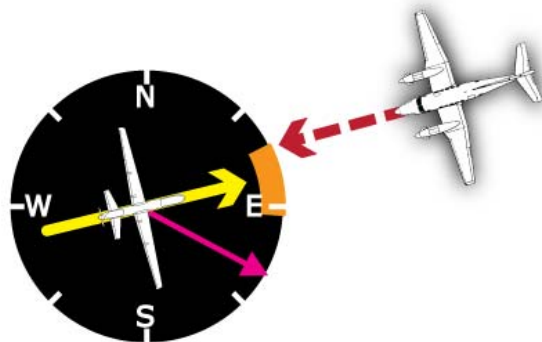
Observations



DAIDALUS Display at Time of Maneuver

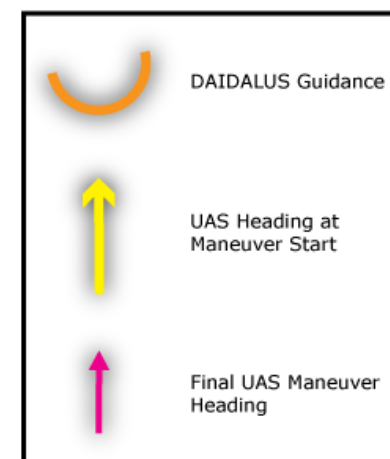
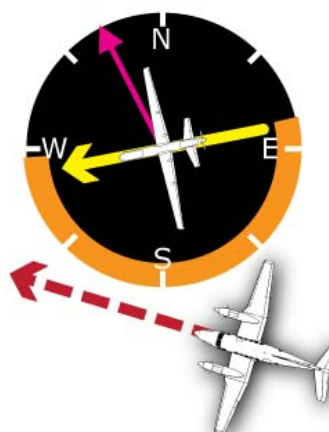
Encounter S12

- Sensor: Radar+ADS-B
- Encounter Type: 0°
- CPA Offset: 1nm
- Aircraft Distance at Maneuver: 9.18nm
- Estimated time to CPA at Maneuver: 102.5 seconds

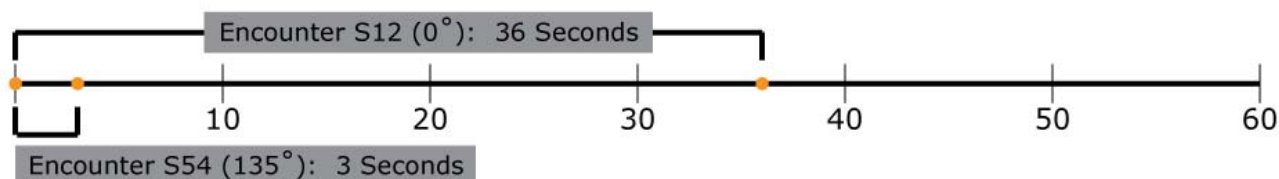


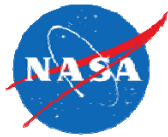
Encounter S54

- Sensor: Radar+ADS-B
- Encounter Type: 135°
- CPA Offset: 0nm
- Aircraft Distance at Maneuver: 2.32nm
- Estimated time to CPA at Maneuver: 73.4 seconds



UAS Operator Time to Maneuver from Start of Guidance

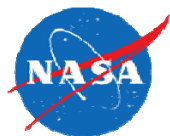




Summary



- Phase 1 MOPS flight testing and validation of simulation results
- Successful test of DAIDALUS in operational flight test conditions with real aircraft and sensors operating in real time
- Initial Aircrew Observations Positive
- Flight Test 3 continues the DAA Flight Test Campaign adding multi-intruder encounters, vertical geometries, high speed aircraft to fully inform and validate the DAA MOPS creation



Backup Slides

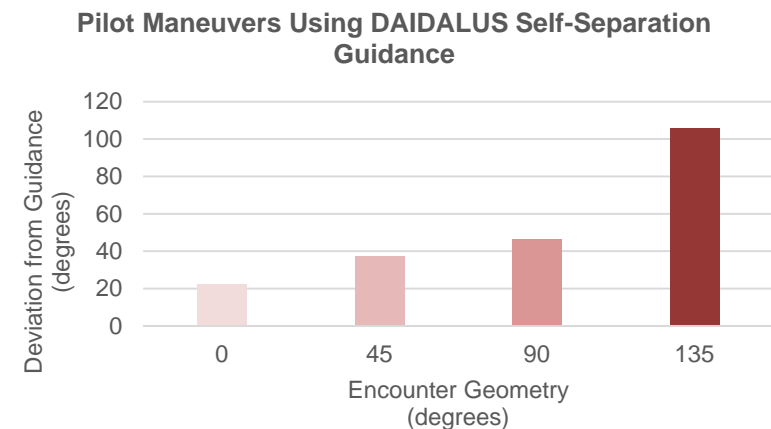


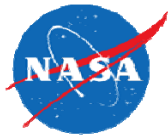


Observations



- The operator made more dramatic maneuvers than needed
 - Operator “primed” by collision avoidance trials in weeks leading up to flight
 - Will provide more timely training before trials in Flight Test 3



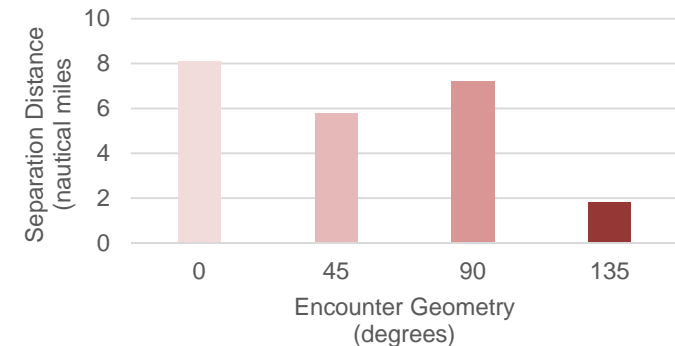


Observations

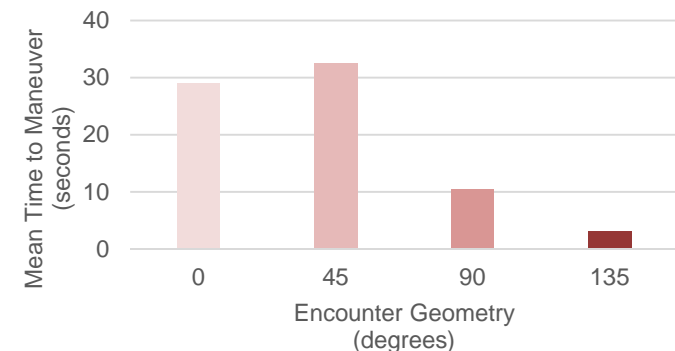


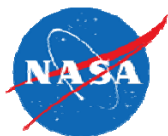
- Alerting time afforded by DAIDALUS reflected in operator behavior
- The operator reacted more urgently in 90 and 135 degree encounters
 - Waited less
- DAIDALUS guidance allowed the operator to stay well clear in the challenging 135 degree encounters

Mean Aircraft Separation Distance at Time of Maneuver



Mean Operator Time to Maneuver from First DAIDALUS Self-Separation Guidance





Trials

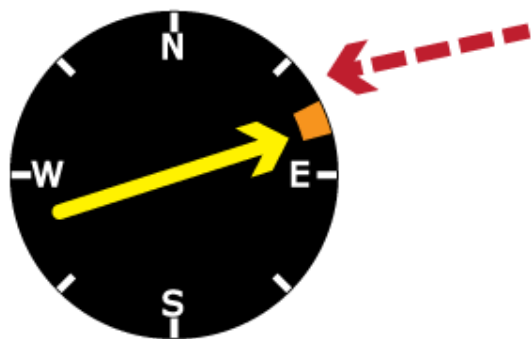


S12

Sensor: Radar+ADS-B
Encounter Type: 0°
CPA Offset: 1nm

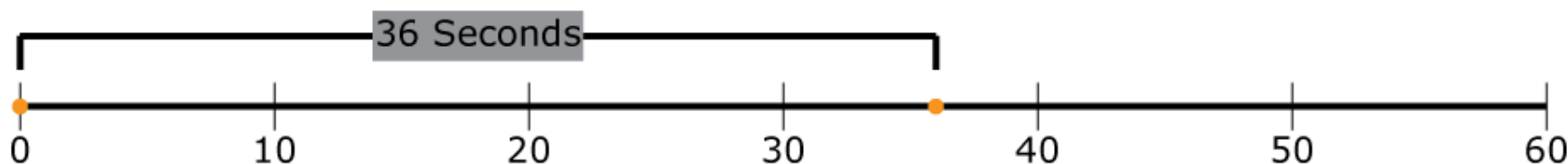
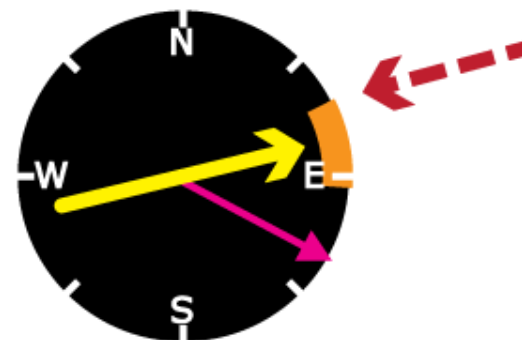
Start of Bands

12.42nm Separation
137.2 seconds to CPA

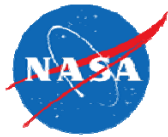


Start of Maneuver

9.18nm Separation
102.5 seconds to CPA



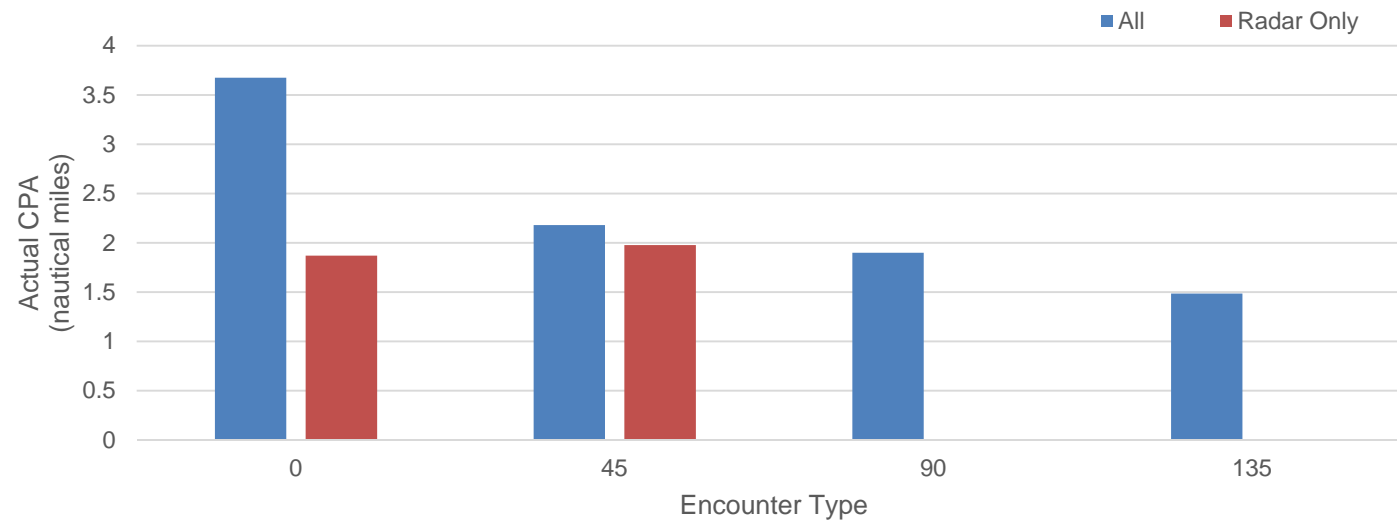
Time from first self-separation guidance to maneuver

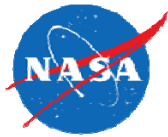


Results

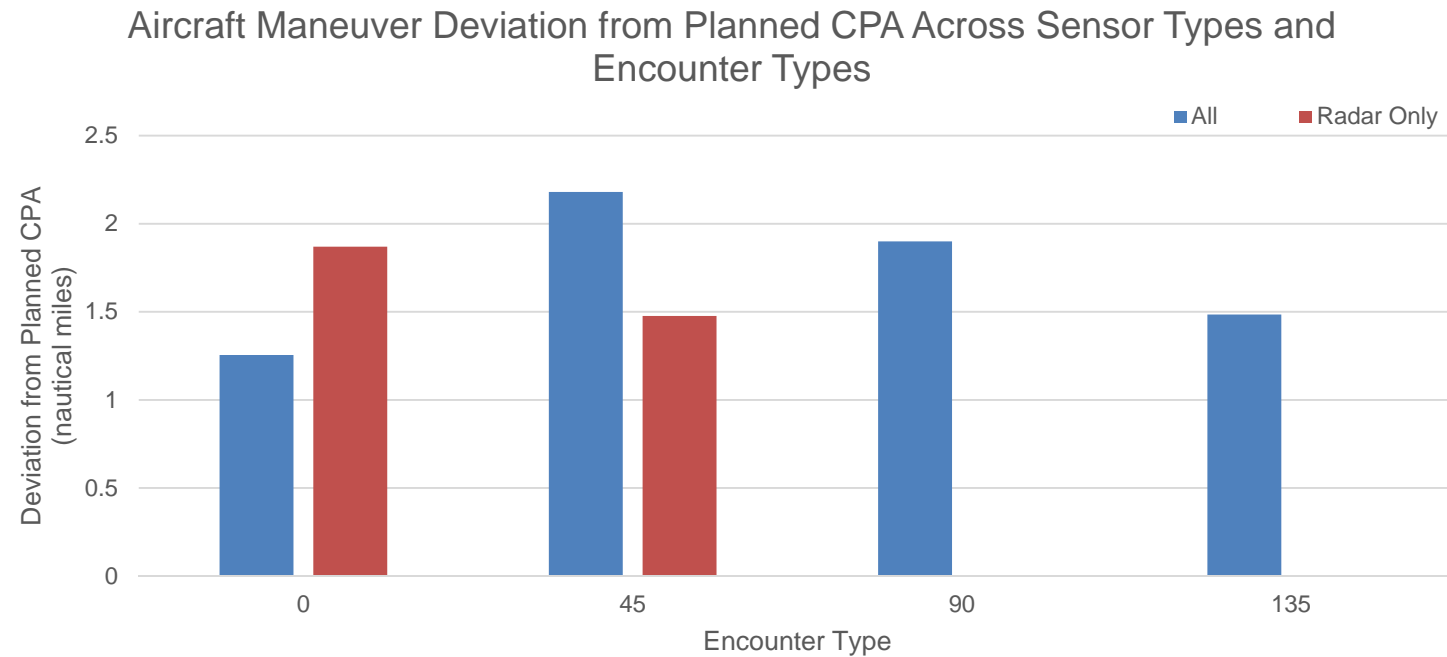


Mean Actual CPA Across Sensor Types and Encounter Types





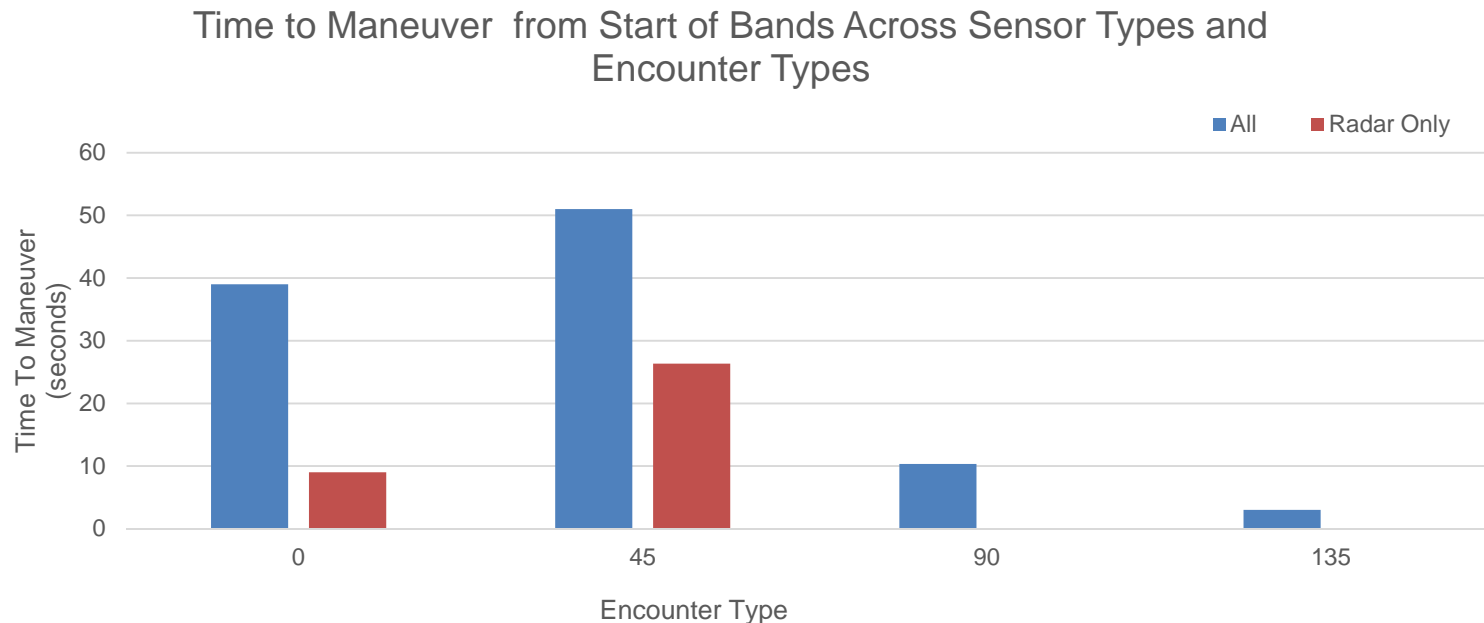
Results



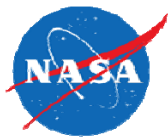
- Radar only deviated more than Radar+ADS-B in 0 degree encounters, but Less in 45 degree encounters



Results



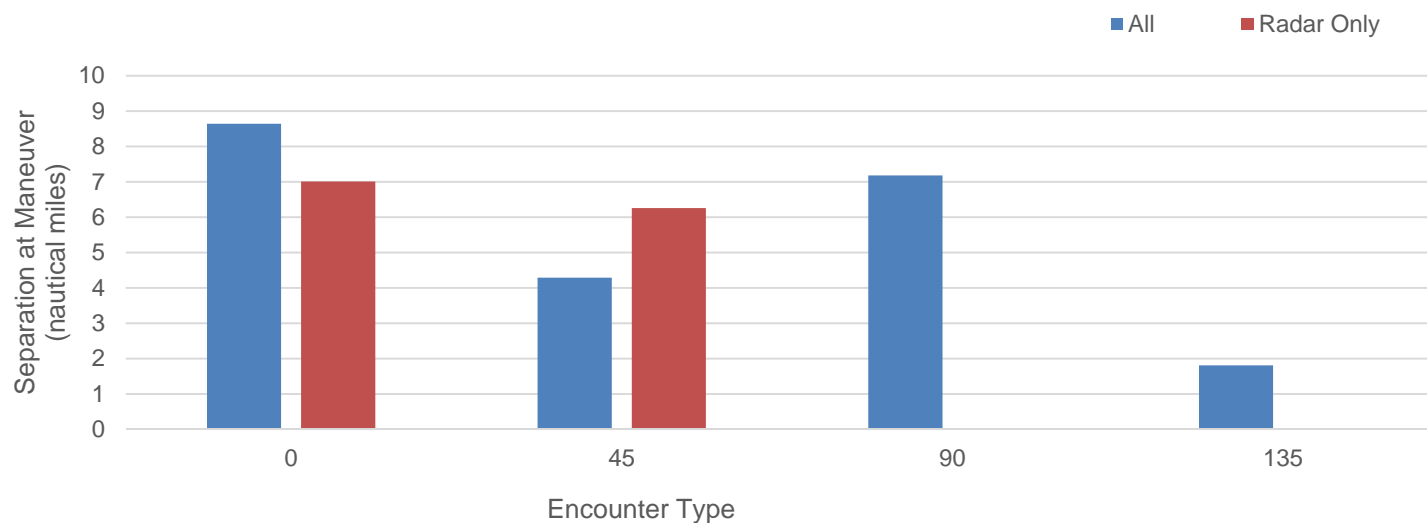
- The UAS operator maneuvered more quickly in 90 and 135 degree Encounters than 45 and 0 degree encounters
- The operator maneuvered more quickly when the onboard radar was the only self separation sensor
 - Limited range of the radar afforded less time and less distance from the intruder to react



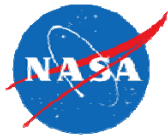
Results



Separation at Maneuver Across Sensor Types and Encounter Types



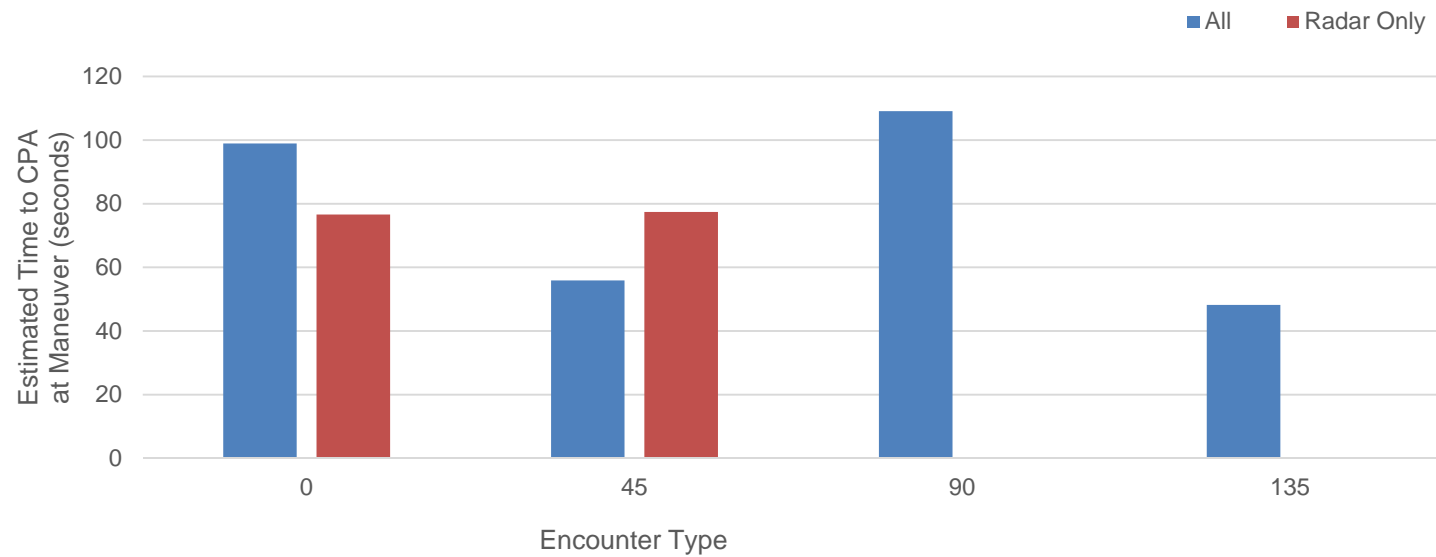
- Separation was lower in the 135 degree encounters at the time of maneuver
- Operator maneuvered at a greater distance in 0 degree with ADS-B+Radar than Radar alone
- The operator maneuvered farther out with Radar alone than ADS-B+Radar



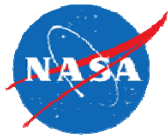
Results



Estimated Time to CPA at Maneuver Across Sensor Types and Encounter Types



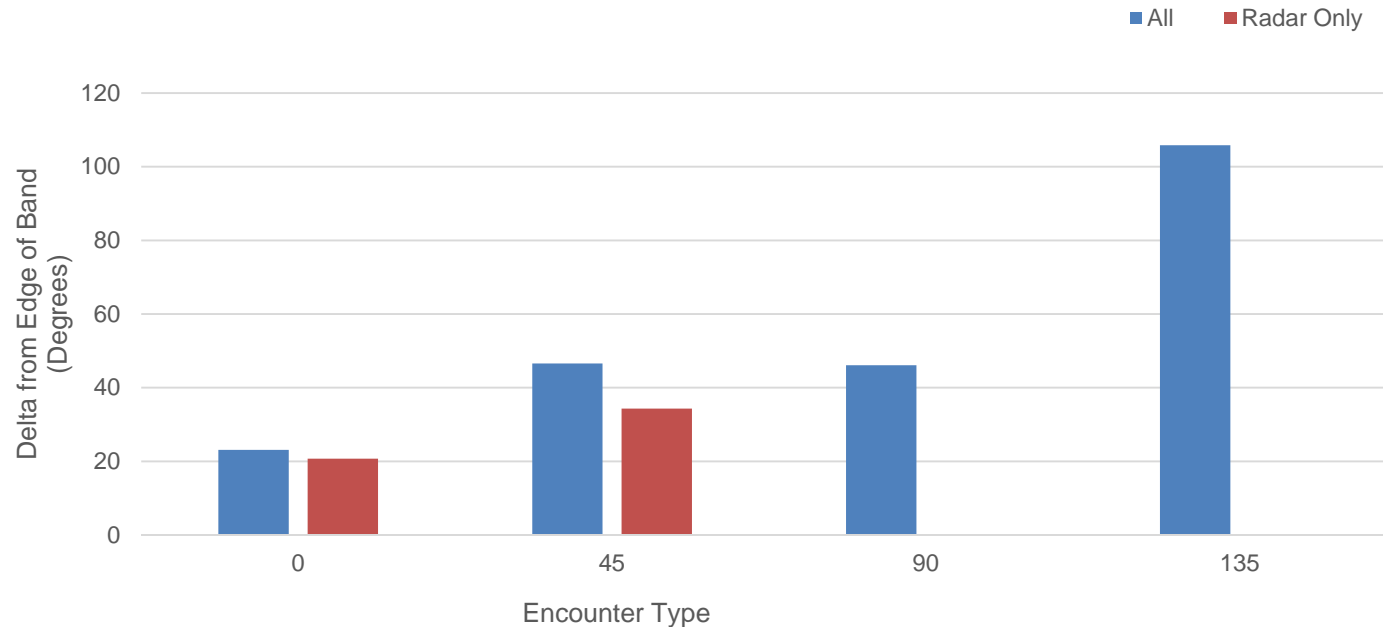
- Similar results to horizontal separation



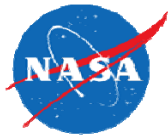
Results



Delta from Band Across Sensor Types and Encounter Types



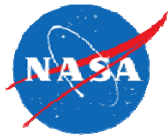
- Overall, the magnitude of the self separation maneuvers were much greater than what Stratway+ indicated was needed. See discussion.
- Maneuver magnitude appeared to be similar between ADS-B+Radar and Radar alone.



Discussion



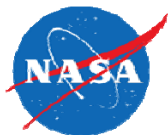
- Encounter geometry appears to have the greatest effect on the self separation Maneuvers.
- For 45° encounters, the operator maneuvered more quickly with radar only Than ADS-B and radar, but had greater horizontal separation at time of maneuver.
 - Opposite was true for 0° encounters
 - Higher comfort level when the intruder track is always present?
- Training and band growth appeared to have the greatest effect on maneuver Magnitude.
 - Training on the Stratway+ display provided 2 weeks before flight.
 - Operator was anticipating the growth of the maneuver. Fixed in current algorithm



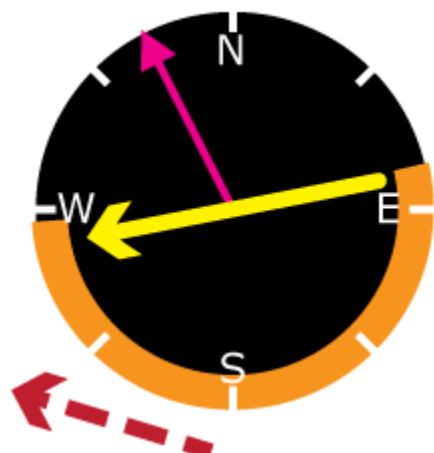
Discussion



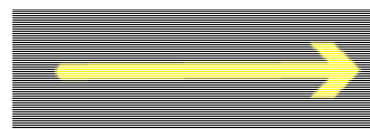
- Excluded trials
 - S24-c: TCAS only condition
 - S35-a: Timing of encounter, 0.5nm CPA offset
 - S36-a: Timing of encounter, 1.0nm CPA offset
 - S34-b: Timing of encounter, outside radar horizon
 - S72: Timing of encounter



Trials



Stratway+ Bands



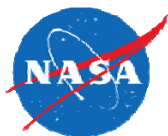
Ownship Heading



Intruder Heading



Final Maneuver Heading



Trials

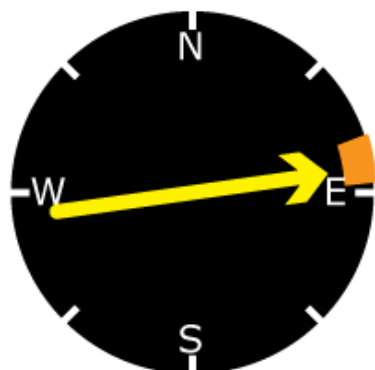


S14

Sensor: Radar
Encounter Type: 0°
CPA Offset: 0nm

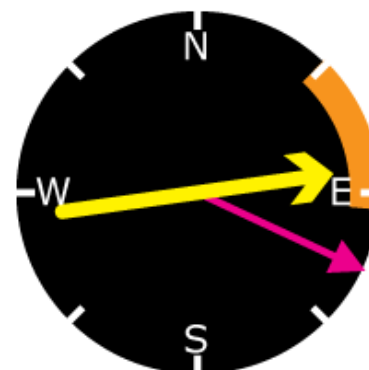
Start of Bands

7.84nm Separation
87.4 seconds to CPA

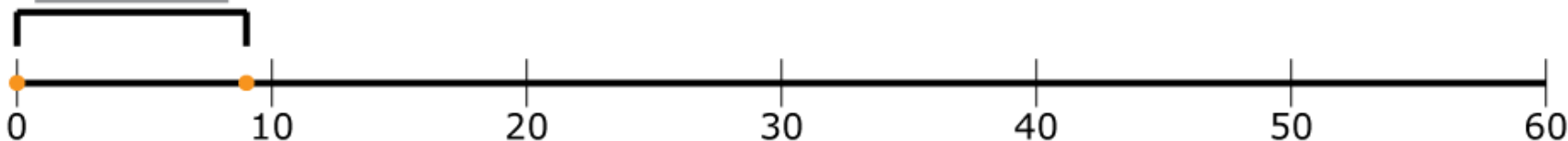


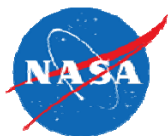
Start of Maneuver

7.01nm Separation
76.6 seconds to CPA



9 Seconds





Trials

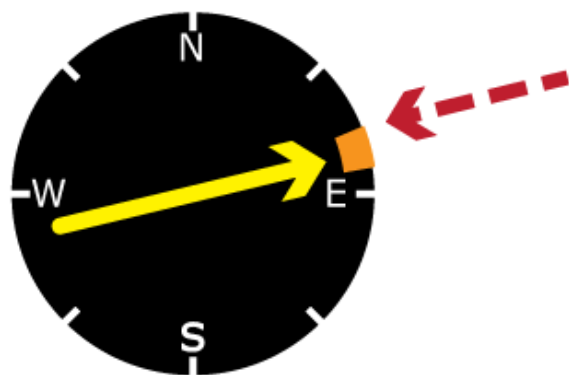


S13

Sensor: Radar+ADS-B
Encounter Type: 0°
CPA Offset: 0.5nm

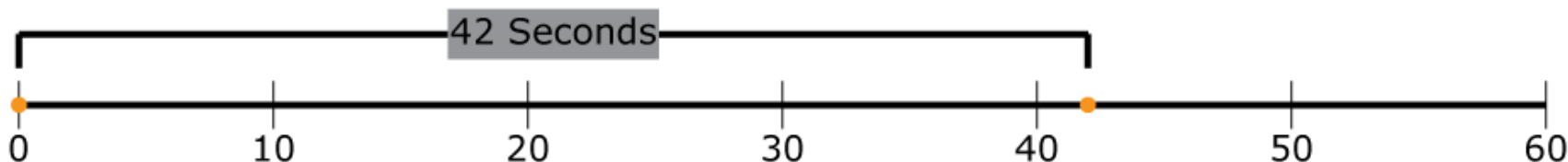
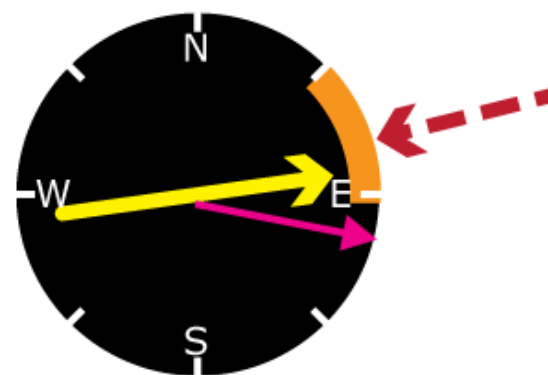
Start of Bands

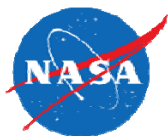
11.65nm Separation
137.9 seconds to CPA



Start of Maneuver

8.1nm Separation
95.4 seconds to CPA





Trials



S24-a

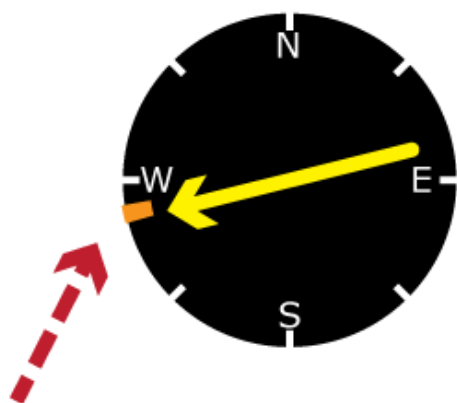
Sensor: Radar+ADS-B

Encounter Type: 45°

CPA Offset: 0nm

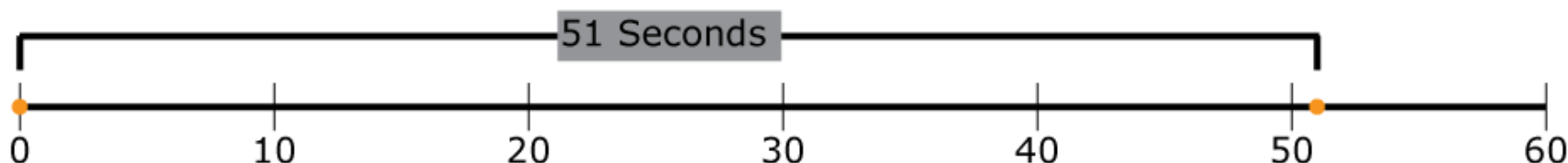
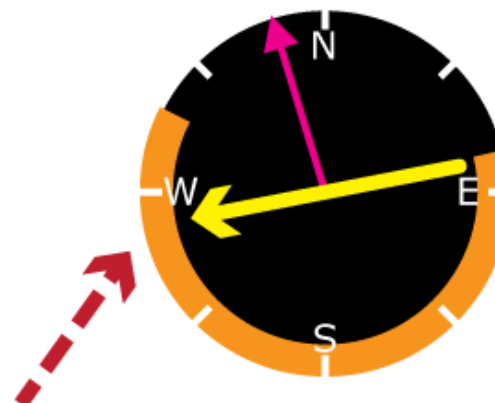
Start of Bands

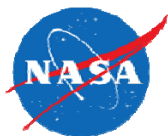
8.2nm Separation
107 seconds to CPA



Start of Maneuver

4.29nm Separation
55.9 seconds to CPA





Trials

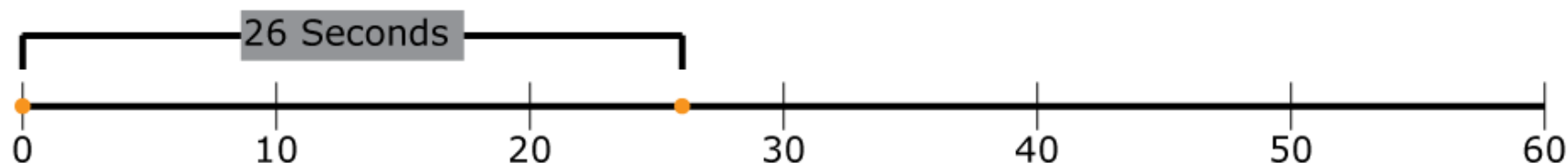
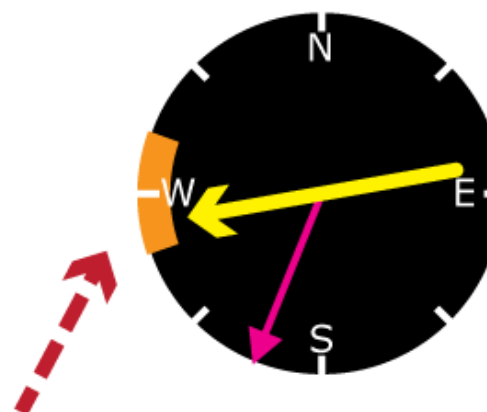
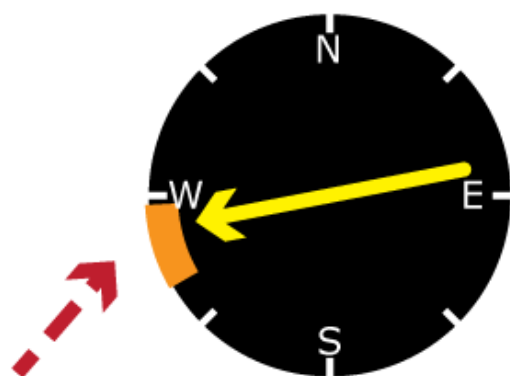


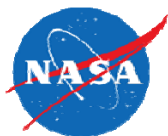
S25-a

Sensor: Radar
Encounter Type: 45°
CPA Offset: 0.5nm

Start of Bands
8.28nm Separation
103 seconds to CPA

Start of Maneuver
6.43nm Separation
86.8 seconds to CPA





Trials

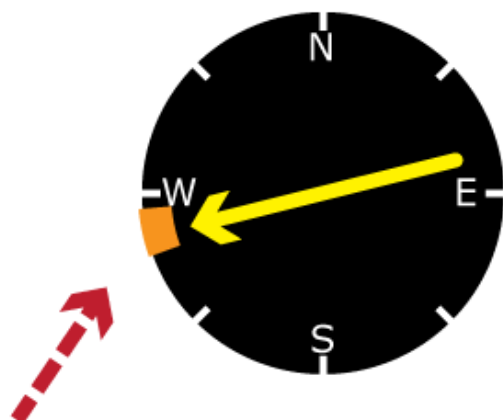


S26-a

Sensor: Radar
Encounter Type: 45°
CPA Offset: 1nm

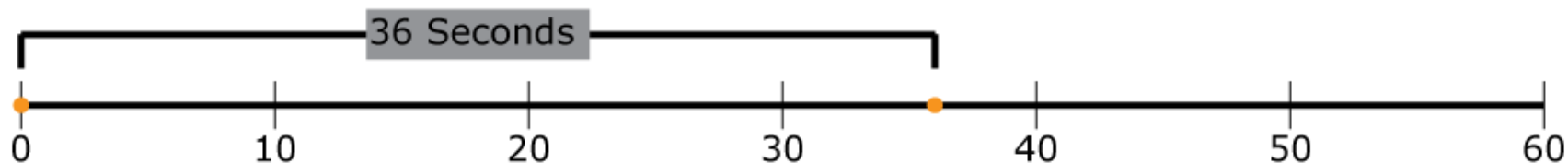
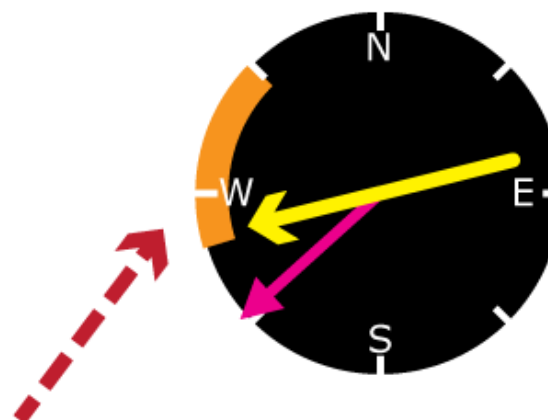
Start of Bands

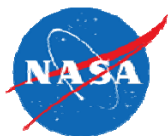
7.92nm Separation
106 seconds to CPA



Start of Maneuver

5.18nm Separation
62.8 seconds to CPA





Trials

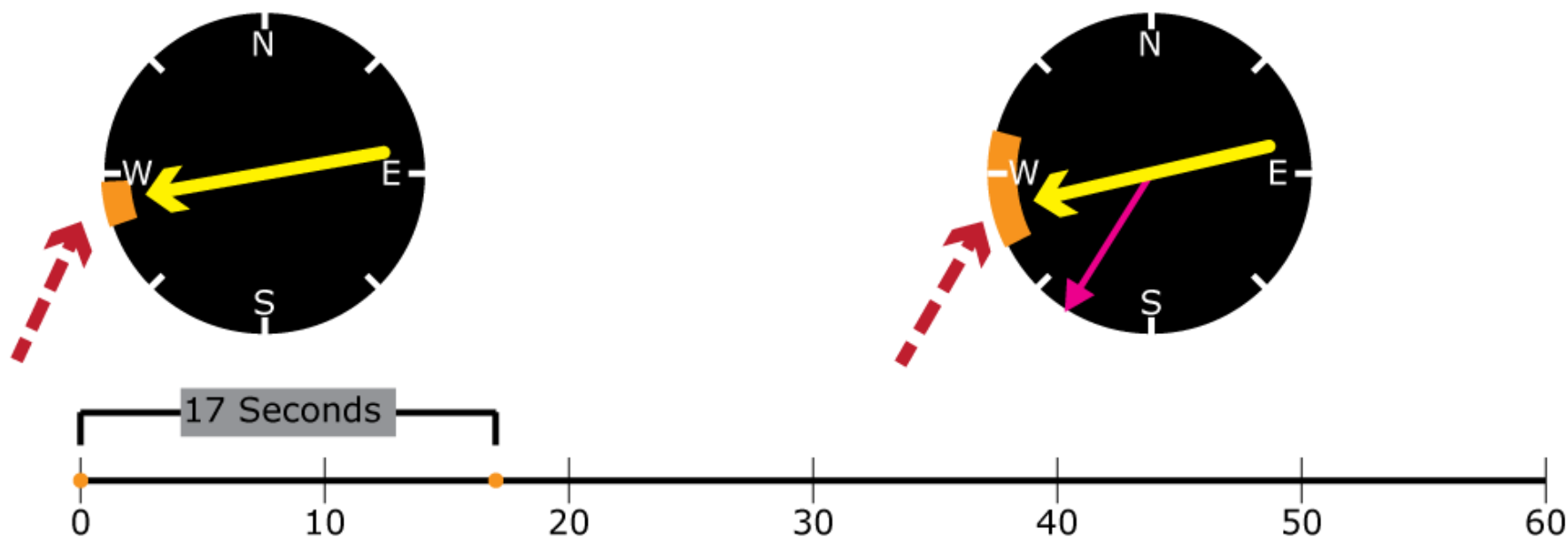


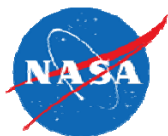
S24-b

Sensor: Radar
Encounter Type: 45°
CPA Offset: 0nm

Start of Bands
8.51nm Separation
106.7 seconds to CPA

Start of Maneuver
7.16nm Separation
82.6 seconds to CPA





Trials



S34-a

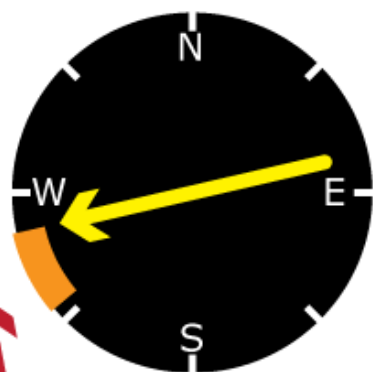
Sensor: Radar+ADS-B

Encounter Type: 90°

CPA Offset: 0nm

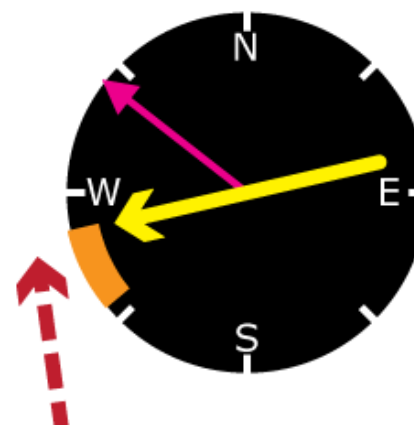
Start of Bands

6.63nm Separation
110.8 seconds to CPA



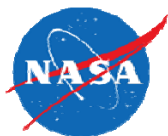
Start of Maneuver

6.57nm Separation
110.1 seconds to CPA



2 Seconds





Trials



S34-c

Sensor: Radar+ADS-B

Encounter Type: 90°

CPA Offset: 0nm

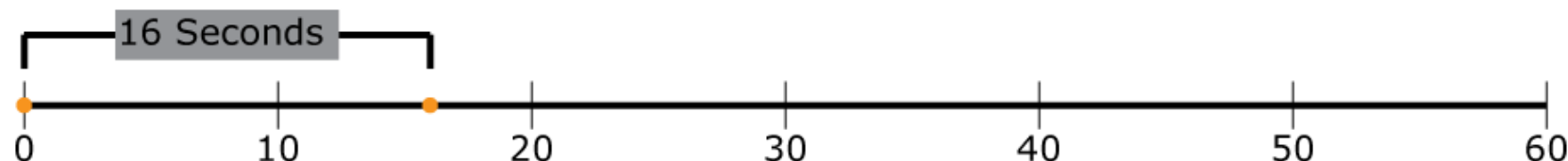
Start of Bands

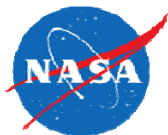
8.55nm Separation
130.3 seconds to CPA



Start of Maneuver

7.46nm Separation
107.7 seconds to CPA





Trials



Text

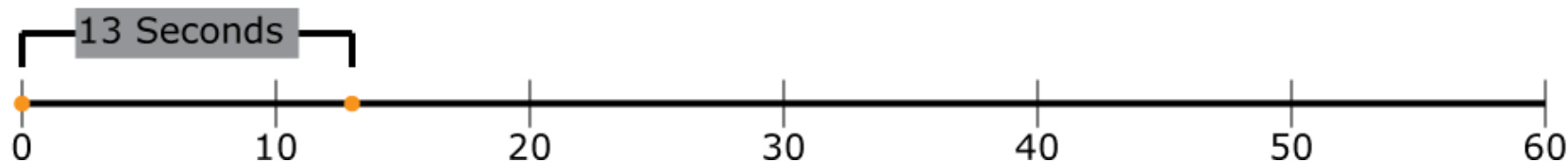
S34-b

Sensor: Radar+ADS-B
Encounter Type: 90°
CPA Offset: 0nm

Start of Bands
8.41nm Separation
124.8 seconds to CPA



Start of Maneuver
7.51nm Separation
109.4 seconds to CPA





Trials



Test

S54

Sensor: Radar+ADS-B

Encounter Type: 135°

CPA Offset: 0nm

Start of Bands

2.4nm Separation
79.6 seconds to CPA



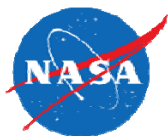
Start of Maneuver

2.32nm Separation
73.4 seconds to CPA



3 Seconds





Trials



Text

S55

Sensor: Radar+ADS-B

Encounter Type: 135°

CPA Offset: 0.5nm

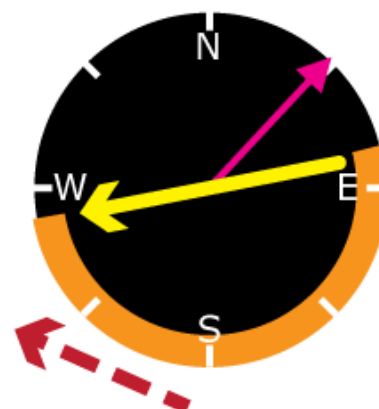
Start of Bands

1.37nm Separation
26.1 seconds to CPA



Start of Maneuver

1.3nm Separation
23 seconds to CPA



3 Seconds

